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EXPERIMENTAL APPLICATION OF AN ELECTROSTATIC ANALYZER ABOARD "COSMOS-12"

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EXPERIMENTAL APPLICATION OF AN ELECTROSTATIC ANALYZER ABOARD "COSMOS-12"

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SUMMARY

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This paper describes the spherical electrostatic analyzer installed aboard the satellites "Cosmos-12" and "Cosmos-15", and applied for the investigations of fluxes of electrons and positive ions with energy $E = 1$ kev. The analyzer had the following characteristics: pass-band width $\Delta E/E \sim 30\%$, sensitivity threshold in the assumption of isotropy of fluxes $\sim 6 \cdot 10^6$ part./cm$^2 \cdot$ sec kev.

The results of measurements during the flight of "Cosmos-12" are presented. It is found that the existing fluxes of electrons and and ions with $E = 1$ kev on the night side of the Earth do not usually exceed the analyzer's sensitivity threshold. Cases were noted to the south of New Zealand of intensity increase of mainly electrons with energy $E = 0.5 \div 1$ kev. Appearance of electrons and ions with energy $E = 1$ kev was registered above the Pacific Ocean.

Author

* * *

The below-described analyzer for the study of electron and positive ion fluxes with energies $E = 1$kev is an electrostatic-spherical type [1, 2]. Analyzers of identical construction were installed on board of satellites "Cosmos-12" and "Cosmos-15". The launching times and their orbital parameters are compiled in the Table 1 (next page).

* OPYT PRIMENENIYA ELEKTROSTATICHESKOGO ANALIZATORA NA SPUTNIKE " KOSMOS-12 ".

TABLE 1

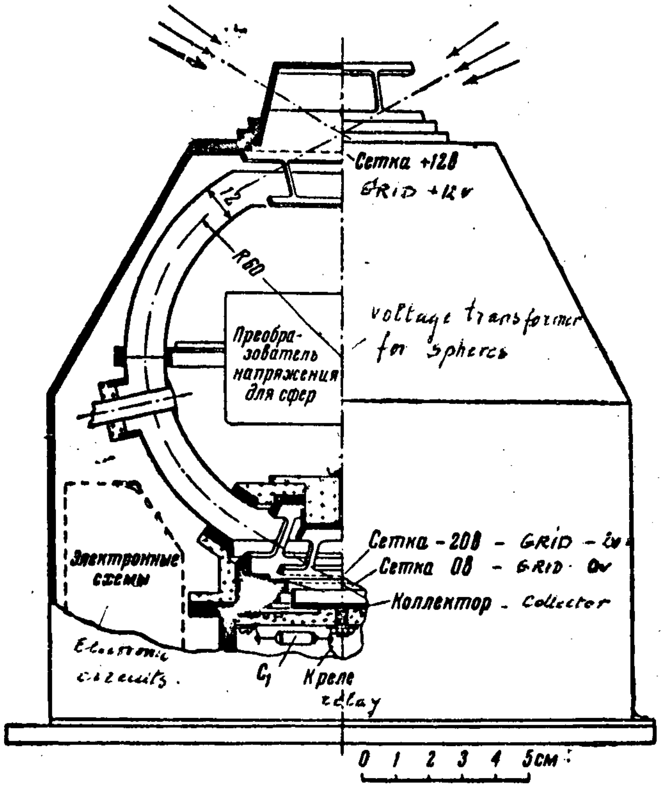
Satellite	Launching	Apogee km	Perigee km	Period min.	Incl. angle of orb. plane
Cosmos-12	22 Dec.1962	405	211	90.45	65°
Cosmos-15	22 Apr.1963	371	173	89.77	65°

The scheme for measuring weak currents induced by the registered fluxes of electrons and ions is described in [2]. American researchers applied electrostatic anal zers aboard the Explorer-XII satellite [3] and on Mariner-II probe [4].

APPARATUS.- In fact a spherical condensor was used as the analyzer (Fig. 1), to the lining of which symmetrical potentials $-U/2$ and $+U/2$ were fed. The charged particles, flying into the gaps of the linings, were deflected by the electric field, hitting the Faraday cylinder at analyzer output.

The deflection angle of particle trajectory, running in the gap along the zero equipotential, is of 120° without taking into account the additional deflection in the scattered field at gap inlet and at its outlet, which does not exceed 2.5°.

The radius of the external surface of the operational gap is 66 mm, that of the internal surface is 54 mm. The linings of the spherical condensor are made of copper; they are especially worked out mechanically so as to allow a decrease of the fraction of charged particles, elastically reflected from the surfaces of the spheres. The thus treated surfaces were then sliver-plated so as to diminish the reflection of light in the ultraviolet region of the spectrum. [5]. The analyzer's spheres are situated inside a thin aluminum casing connected with the satellite frame. A conical input diaphragm is installed on the casing. The geometry of analyzer's input and output diaphragms was chosen in conjunction with the calculations of electro-optical characteristics of a 120°- analyzer [1]. Conical screens, diminishing the effects of scattered fields, are installed directly in front of the gap's inlet and after its outlet; these screens are connected with the frame.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GRID +12v
R60
12
Преобра-
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для сфер
voltage transformer
for spheres
Электронные
схемы
Electronic
circuits.
Сетка -20В - GRID -2v
Сетка 0В - GRID 0v
Коллектор - Collector
C_1
Креле
relay
0 1 2 3 4 5см

Fig. 1

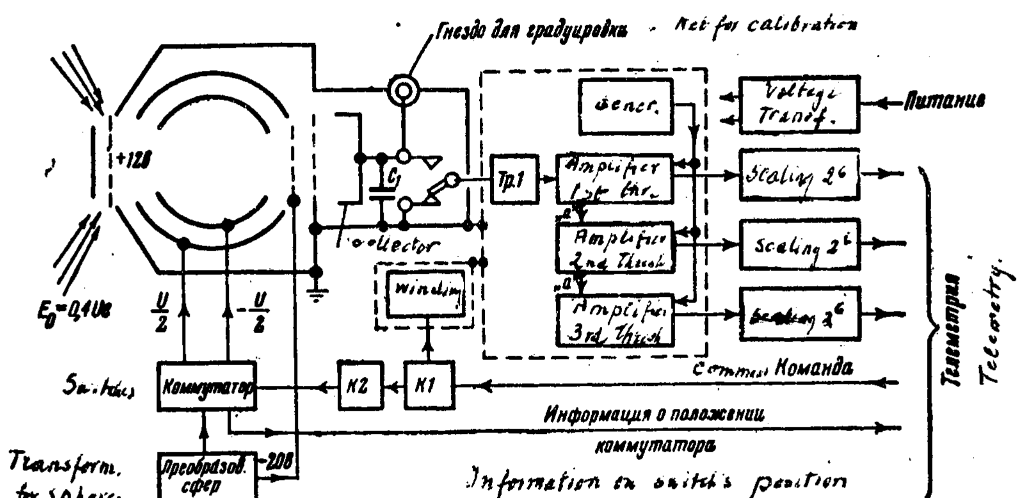
Гнездо для градуировки - Net for calibration
+12В
C_1
collector
Tp.1
Gener.
Voltage
Transf.
Питание
Amplifier
1st thr.
Amplifier
2nd Thresh
Amplifier
3rd Thresh
Scaling 2^6
Scaling 2^6
Scaling 2^6
Winding
E_0=0,4Us
$\frac{U}{2}$
$-\frac{U}{2}$
Switches
Коммутатор
K2
K1
Command Команда
Информация о положении
коммутатора
Information on switch's position
Transform.
for spheres
Преобразов.
сфер
-20В
Телеметрия
Telemetry

Fig. 2

If a flux of charged particles is present in the space outside the analyzer with a directed intensity i (E) particle/cm^2 sec·ster kev, the following flux N emerges from the analyzer

$$N = \int_{E_0-\Delta E/2}^{E_0+\Delta E/2} i(E)L(E)dE \text{ particle/sec.}$$

Here L (E) is the analyzer transmission; $E_0 - \Delta E/2$ and $E_0 + \Delta E/2$ are the edges of the pass band. In order to estimate the geometric factor G of the analyzer, we shall represent the shape of the line L (E) of the analyzer in the form of a triangle with the altitude $L(E_0) = L_0$ and the base ΔE. We shall also substitute $i(E_0)$ for $\bar{i}(E)$. Then,

$$N \simeq \bar{i}(E_0) \int_{E_0-\Delta E/2}^{E_0+\Delta E/2} L(E)dE = \bar{i}(E_0)L_0\frac{\Delta E}{2} = \bar{i}(E_0)L_0\frac{\Delta E}{E_0}\frac{E_0}{2} = \bar{i}(E_0)G.$$

and hence

$$G = \frac{1}{2}L_0\left(\frac{\Delta E}{E_0}\right)E_0 \text{ cm}^2 \text{ ster kev.}$$

According to the computations [1], $L_0 = 0.066\ r_0^2$ cm^2 steradian for the described analyzer, without taking into account the shading effect of the output diaphragms, where r_0 is the radius of the mean equipotential in the gap. Such value of L_0 is maximum possible ($L_{0\,max}$) and in the considered analyzer $L_{0max} = 2.4$ cm^2 ster at $r_0 = 6$ cm. The maximum relative pass band width, computed in [1] and determined only by particle hitting the surface of the spheres, is $(\Delta E/E_0)_{max} = 6a = 0.6$, where $a = \Delta r/2r_0 = 0.1$. The minimum value $(\Delta E/E_0)_{min}$, referred to the particles entering the gap along the tangential to the mean equipotential and flying in the meridional plane, is equal for the analyzer described to 0.08 [1].

For a real device, it is necessary to take into account the decrease of the pass band $\Delta E/E_0$ and of the aperture ratio of L_0 by comparison with their maximum values on account of the influence of diaphragms, of the finite dimension of the collector and of partial shading of the latter by the grids, that is $L_0 < L_{0\,max}$ and $(\Delta E/E_0)_{min} < \Delta E/E_0 < (\Delta E/E_0)_{max}$. Admitting $\Delta E/E_0 \sim 0{,}3$; $G \sim 0{,}1\ E_0$ cm^2 ster, we shall obtain $G \sim 0{,}1\ E_0$ cm^2 ster·kev.

The energy E_o in the pass band maximum for the considered geometry of the deflecting condensor is linked with with the potential difference on linings by the expression

$$U(v) = 0.4 E_c \text{ (ev)}.$$

The potentials were fed to linings from a high-voltage transformer in the inner sphere by way of a high-voltage switch (Fig. 2). The value of the potential difference and its sign were subject to changeover on command in flight. The analyzer installed on Cosmos-12 could be tuned for the registration of electrons with energies $E_o = 1$ kev. For one of the four positions of the switch both spheres were connected with the device's frame. To prevent the thermal ions of the ionosphere hitting the operational gap, the analyzer input, installed on Cosmos-15, was covered by a grid, to which a + 12 v potential relative to satellite frame was fed.

The Faraday cylinder (Fig. 1) served as particle collector of the analyzer; this cylinder of made of duralumin and fastened on an isolator made of polished plexiglass. The inner surface of the Faraday cylinder was finned, so as to diminish the escape of secondary electrons. From the bottom side the collector is surrounded by screening metallic parts of the device. The collector's inlet window is covered up by two grids, the nearest of which being connected with the frame of the device, whereas the following is sustained at − 20 v potential relative to frame in order to suppress the secondary electrons and photoelectrons from the Faraday cylinder. The grids weaken also the capacitive link between the collector and the spheres, on which high voltages change periodically over. The current of particles, hitting the collector, was measured with the help of an electrometric circuit, applying the principle of charge accumulation on the condensor C_1 during the time T and the transformation of the value of accumulated charge into a number of pulses [2].

Pellicular polystyrene condensors of 100 $\mu\mu f$ capacitance were used for the storage condensor. The resistance leakage of such condensors is no less than 10^{13} ohm , and the absorption factor $\sim 10^{-3}$.

The electrometric circuit allowed to measure currents, beginning with $\sim 8 \cdot 10^{-15}\,a = 5 \cdot 10^4$ particle/sec $= N_{min}$. Such a current on collector corresponded to intensity minimum of the global current

$$\bar{I}_{\min}(E_0) = 4\pi\bar{i}(E_0) = 4\pi\frac{N_{\min}}{G} \approx 6\cdot10^{6}\frac{1}{E_0} \text{ particle/cm}^2\text{• sec kev.}$$

The dynamic range of the circuit is $\sim$ 1000. The time of charge accumulation T = 120 sec ; it was determined by the repetition rate of the on-board command guidance feeding into the cell K1 (Fig. 2). The latter formed a pulse of $\sim$200 msec duration to close the discharge relay of the storage condensor. The cell K2 was started by this pulse's rear front, forming in its turn a pulse for starting the weak-current relay, through the contacts of which the current was fed to high-voltage switch winding. The pulse for the action of the switch's armature was somewhat detained in the induction windings of the relay and switch, and this is why the attraction of the armature of the switch took place when the storage consdensor already had time to discharge itself and the input of the electrometric circuit to frame was closed. The high-voltage change-over on spheres took place during the reverse course of the switch's armature.

The high-voltage transformer, the switch and the electrometric circuit were situated in the external compartment of the device, situated on the exterior surface of the satellite. (See Fig. 1). The scaler, the command cells and voltage tranformer were disposed inside a hermethized container. During charge accumulation the state of the triggers together with the information on the number of the position of the switch were telemetered. In the presence of current on collector, the state of triggers varied immediately upon the passing of a series of pulses from the electrometric circuit.

The alignment, the calibration of the circuit and the preflight checking were conducted with the aid of a weak current, fed from control board through the calibration nest [2].

Results of "Cosmos-12".- The preliminary results of measurements on Cosmos-12 and Cosmos-15 with the help of analyzers were communicated in reference [6]. The readings from Cosmos-12 analyzer for the period from 22 to 30 December for the convolutions when the information on the operation of the analyzer was available, are plotted in Fig. 3.

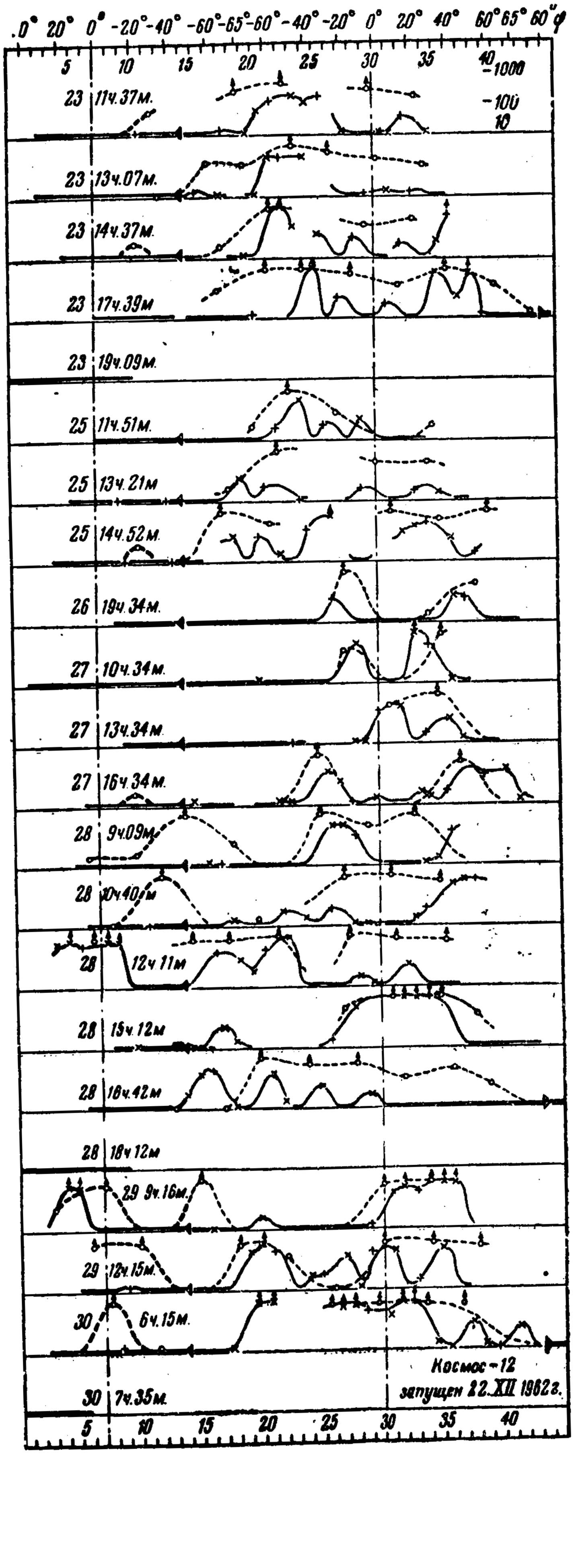

Fig. 3

[Explanations]

The time in units T of the interval of charge accumulation on condensor C_1 is plotted along the horizontal axes.

The solid and dotted lines of each "level" refer to one of the convolutions.

For each of the convolutions the potential difference on storage condensor is plotted along the vertical axis in millivolts.

The sensitivity threshold of the circuit, of about 10 mv, corresponds to global intensity

$$I \sim 6 \cdot 10^6 \text{ part/cm}^2 \cdot \text{s kev}$$

for the energy $E_0 = 1$ kev. For the orientation a scale of geographical latitudes was added from above and expressed in degrees.

At intersection points of horizontal axes with vertical dashed lines, ———— the satellite passes through the equator at night and day sides of the Earth. The numbers from left indicate the date and time of passing the night equator at the given convolution. Circles refer to the case when the deflecting field in the analyzer gap is absent, and crosses - to positive ion tuning, with oblique crosses - to tuning to electrons. The curves are drawn only for perception since the experimental points are scarce. Heavy portions of curves correspond to satellite passing in Earth's shadow.

When searching for the tines of satellite entry into the Earth's shadow or exit from it, its trajectory was projected on the plane xy, perpendicular to the direction Earth-Sun.

It is evident, that two out of four intersections of orbit's projection with that of the Earth's surface (disregarding the atmosphere refraction) should give the times of satellite entry into the Earth's shadow and its egress from it.

Calculations show, that during several days of Cosmos-12 flight the latitude of exit from shadow hardly varied and was equal to -46°. The geographical position of night portions of the trajectory for the convolutions, already considered in Fig. 3, is shown in Fig. 4. The thin solid lines correspond to portions of trajectories, where the information on analyzer operation was available. The heavy dashed and solid lines along the trajectory, and also the numerals near it, have the same meaning as in Fig. 3. For the 26th convolution (19 34 hrs) the daylight branch is brought up.

From the consideration of both figures 3 and 4, together with the deduction of analyzer's normal operation, we may derive the following conclusions.

1.- Prior to 28 December, the constantly existing intensity of electrons and ions with energy ~ 1 kev was less than $6 \cdot 10^6$ part/cm^2 sec kev in the assumption of isotropy. An increase intensity ($\sim 10^8$ part/cm$^2 \cdot$ s kev) of electrons and ions with energy ~ 1 kev was registered by the analyzer above the equatorial regions of the Pacific Ocean on two orbits, 28 (12 11 h) and 29 (09 16 h), which may possibly be related to the solar flare of force 1 having taken place on 24 December.

It is interesting to note also the appearance of signals from analyzer output in the absence of the deflecting field in the gap on the night portions of orbits 23 (11 37 h., 13 07 h., 14 37 h.), 25 (14 52 h.), 27 (16 34h.) 28 (09 09 h., 10 40 h., 15 12 h.), 29 (12 15h.) in the vicinity of values 10-15 of the lower scale of Fig. 3. The regions of these signals' appearance are grouped near the magnetic sheath with $L \sim 1.4$, which allows to make the assumption of registration in this region of low-energy particles, connected with the existence of the inner radiation belt, which penetrate to the collector upon reflection from the operating surfaces of the analyzer. However, it is difficult to estimate the energy and the intensity of such particles. One may only state, that if they are electrons, their energy should exceed 20 ev.

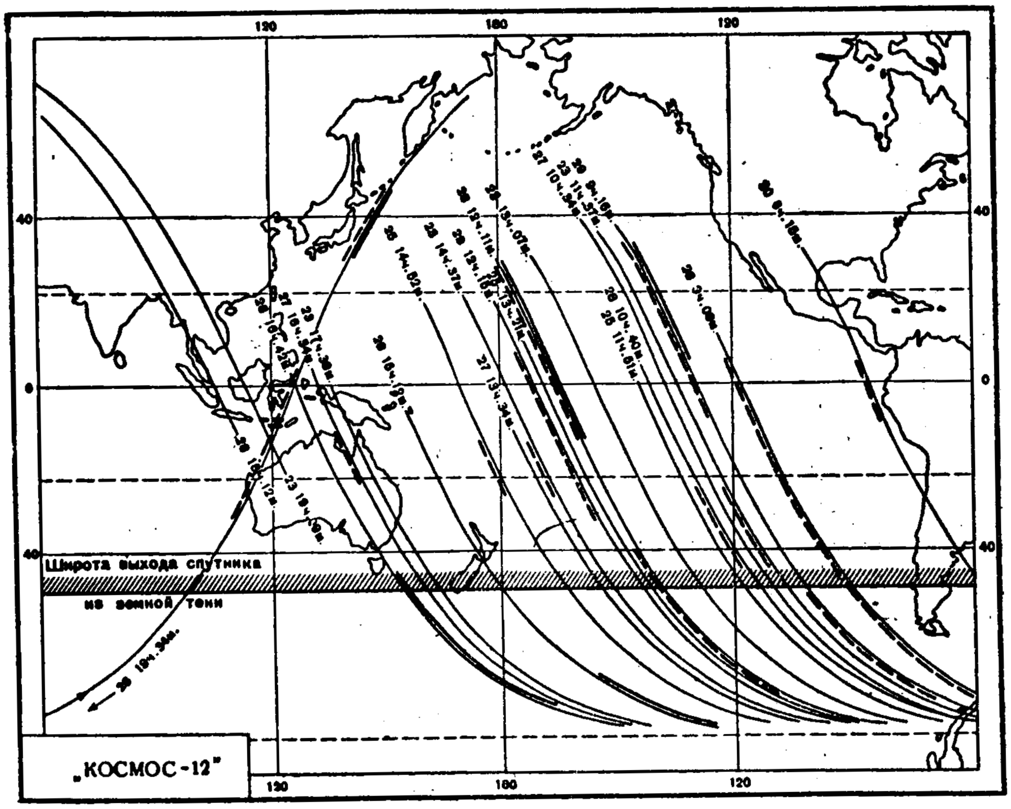

Fig. 4

2. - Over the daytime portions of all orbits, no constant intensity level of any kind was observed for electrons and ions with energy ~ 1 kev, exceeding $6 \cdot 10^6$ particle/cm^2 sec kev. However, signals, strongly varying in magnitude, emerged from the analyzer at every passage by the satellite of the illuminated side of the Earth. These signals may be induced by photoelectrons from collector grids (crosses) or by aggregate action of photoelectrons and thermal ions of the ionosphere, penetrating through gaps between spheres. The shape of the curves is apparently linked with the character of satellite somersaults.

3.- Over neighboring orbits (convolutions) 28 (15^{42}h. and 16^{42} h) in the region to the south of New Zealand cases of increased ($\sim 10^8$ part/ cm^2 sec kev) intensity of charged particles were registered. This region is situated in the vicinity of the southern isochasm.

In conclusion the authors express their thanks to V. Ya. Shiryayeva, and N. M. Safronova for their help in constructing the device, and also to Yu. V. Trigubov and L. A. Smirnov for adjusting the device and the preparation for its launching.

*** THE END ***

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